April 16th 2024

Materializing your metal additive manufacturing journey

Set an ambition goal which could be used as a North Pole star across the organization

AMSL machine with a targeted AM content of 30%?

Metal AM examples

GE Additive

CFM56

NO additive part

LEAP

28 parts

GE9X

250 parts

Catalyst

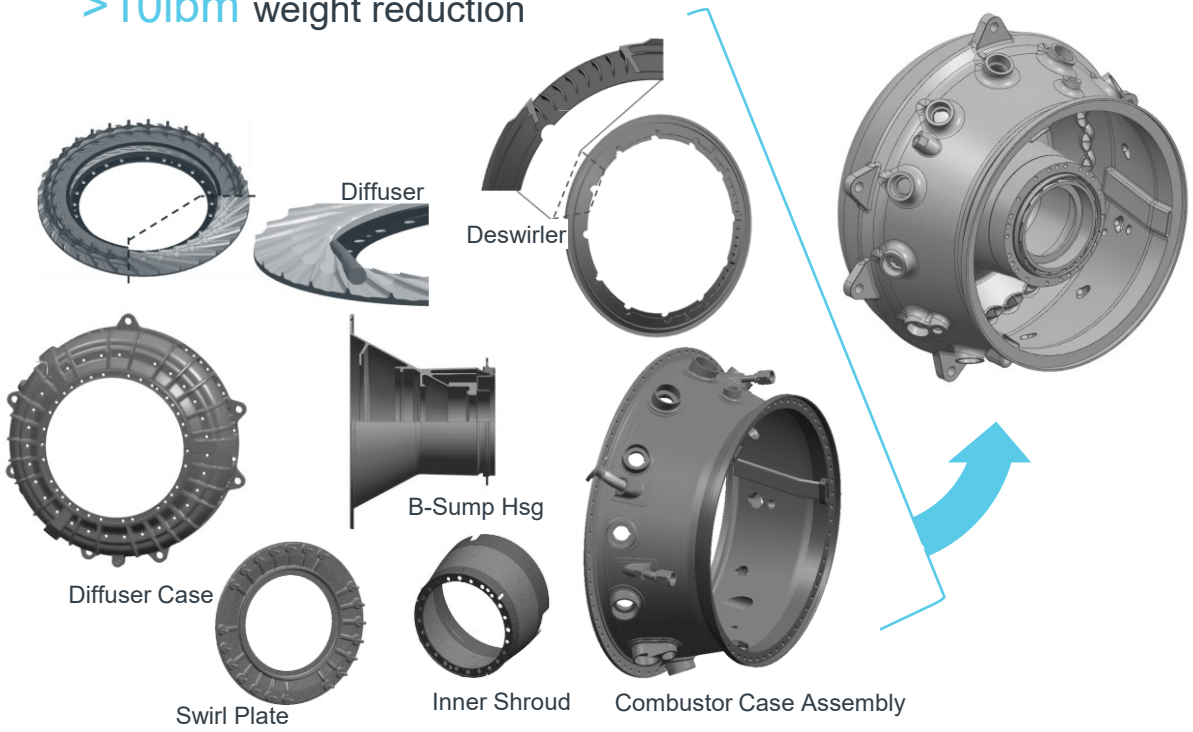
30% of engine weight (targeted)

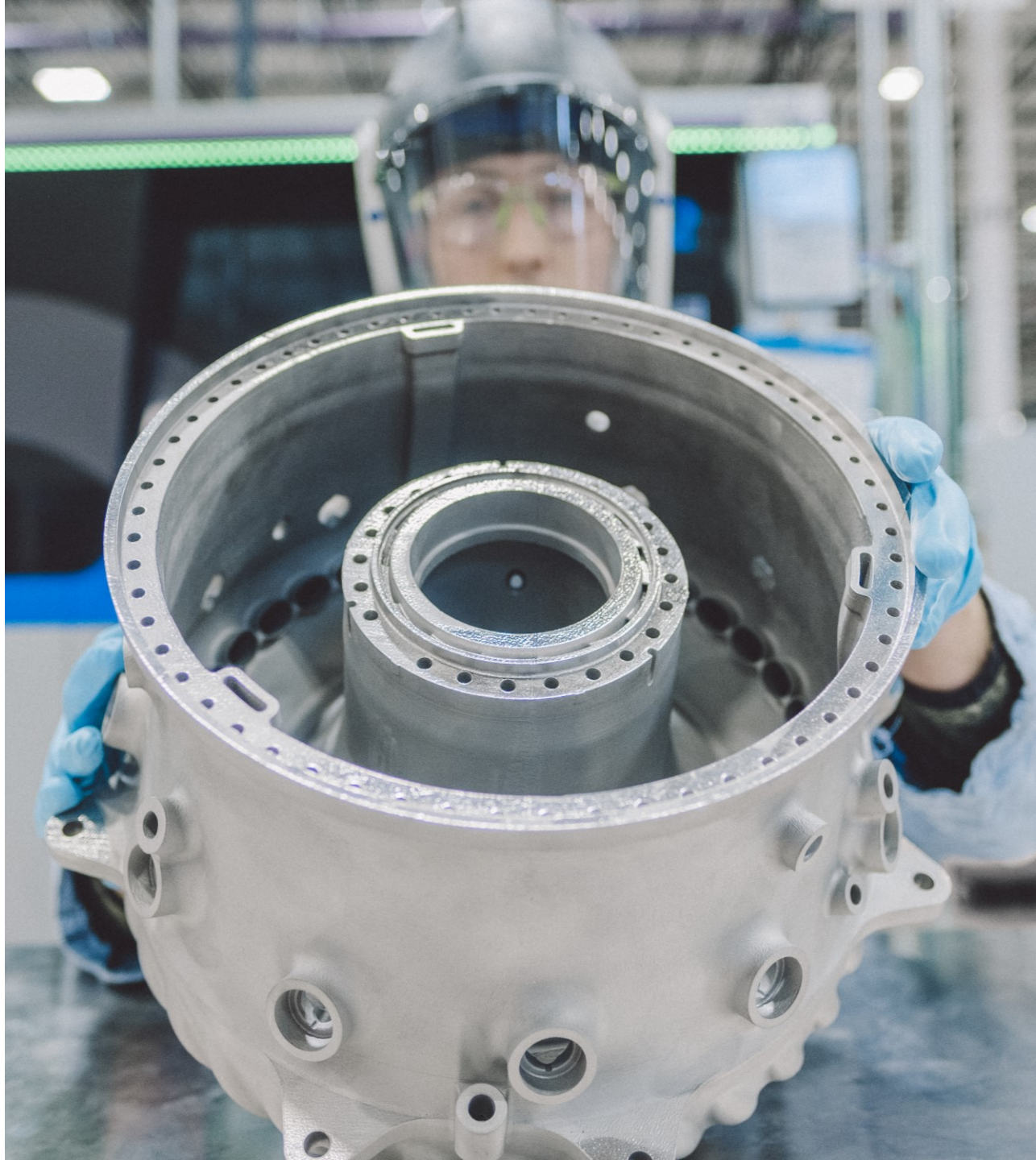
Reduction of assemblies

7-to-1 assembly reduction

~300-to-1 part reduction

>10lbm weight reduction

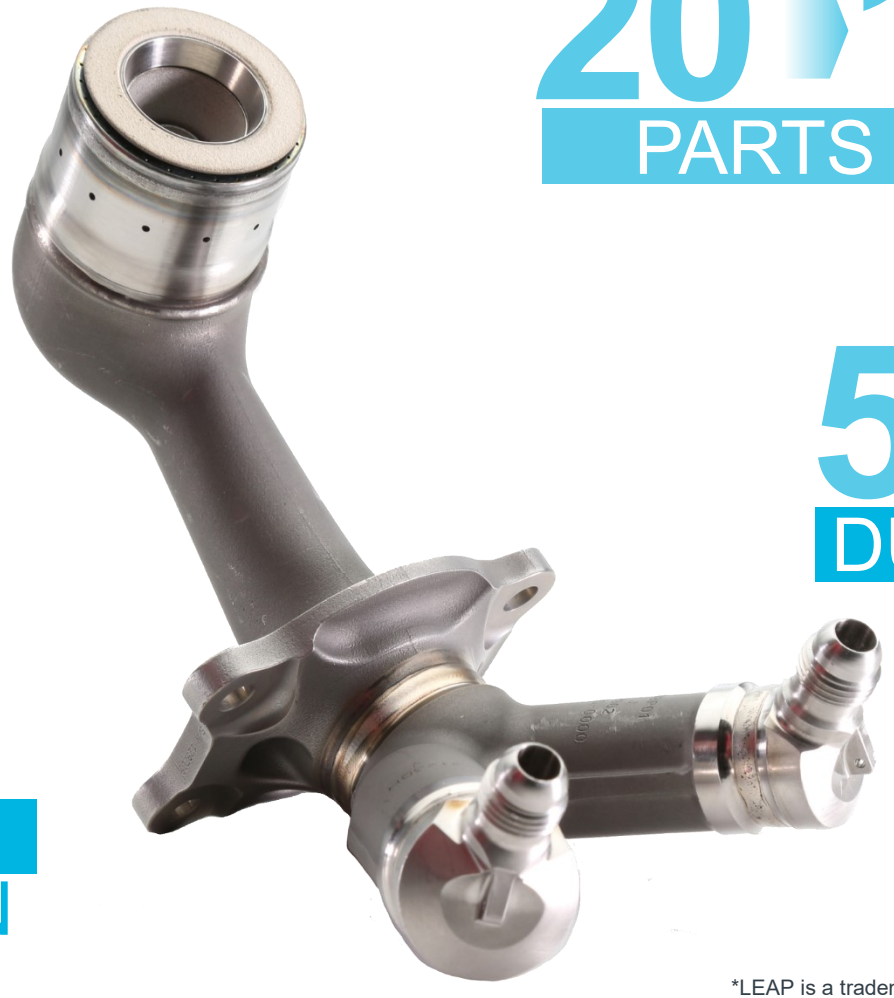




LEAP fuel nozzle tip*

20 → 1
PARTS

30%
COST EFFICIENCY IMPROVEMENT



5x MORE
DURABLE

95%
INVENTORY REDUCTION

25%
WEIGHT REDUCTION

Source: GE Aviation

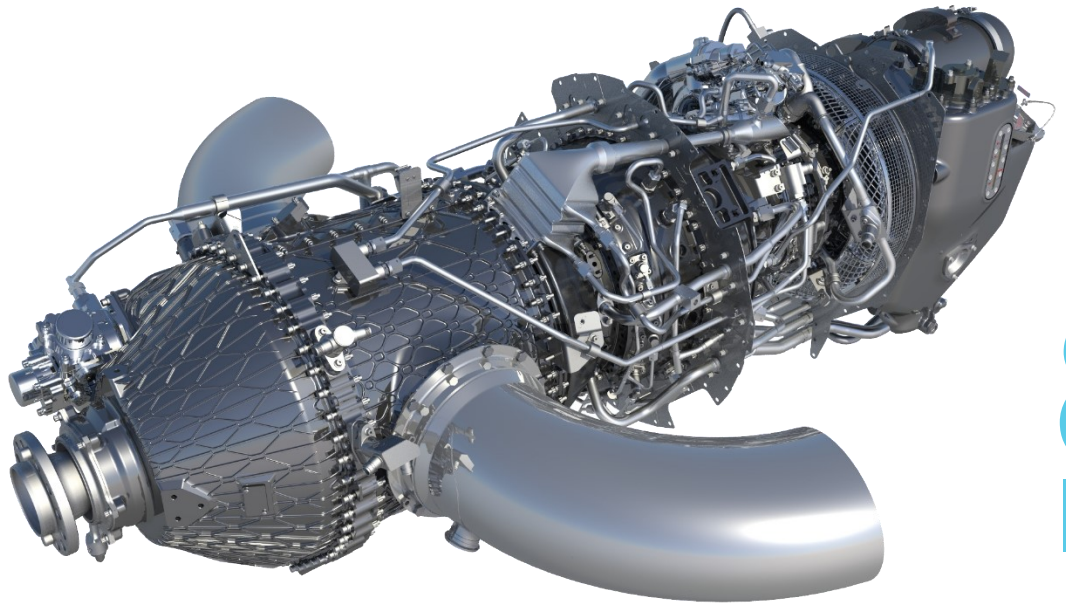
*LEAP is a trademark of CFM International, a 50/50 JV between GE and Safran Aircraft Engines.

Comparison versus TAPS fuel nozzle

System improvement* for the Advanced Turboprop

Combustor test schedule reduced from **12 months** to **6 months**

20%
LOWER MISSION FUEL BURN



5%
WEIGHT REDUCTION

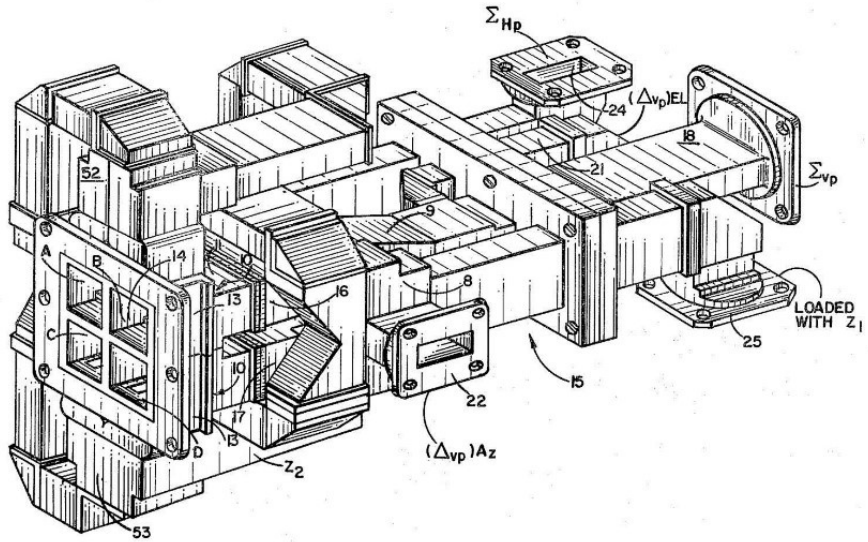
855 → 12
PARTS

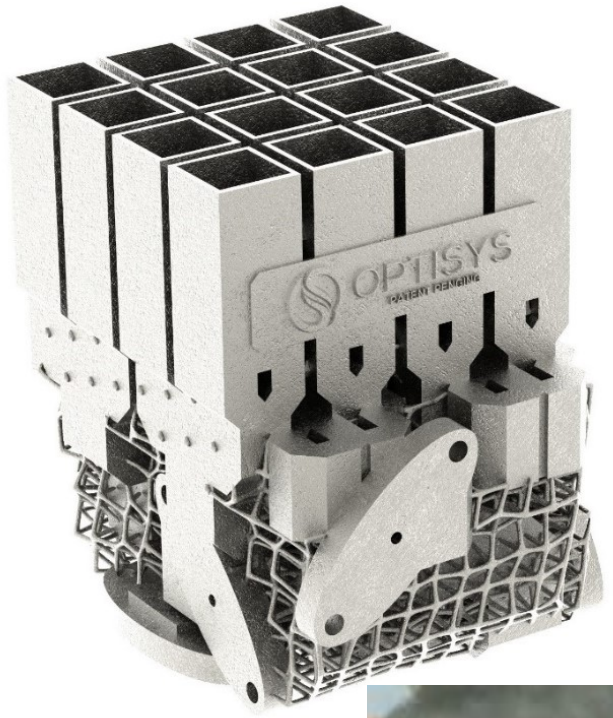
Source: GE Aviation

* Weight reduction completely attributed by additive; fuel burn improvement is partially attributed by additive

Satellite Optisys‘ RF antenna: 100-parts-to-1 simplification

Optisys redesigned a large, multi-part antenna assembly (left) into a palm-sized, lighter, one-piece, 3D-printed metal antenna (right). The component was manufactured with a Concept Laser Mlab machine to provide optimum radio frequency (RF) performance.





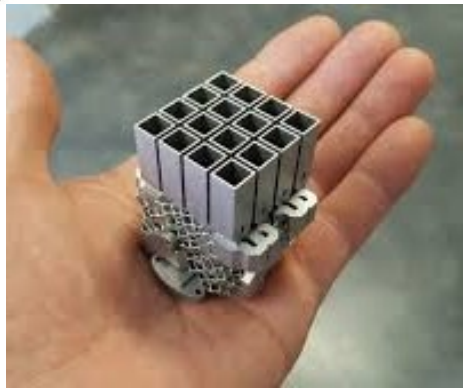
95% weight reduction

75% reduction in non-recurring costs

11-to-2 months lead time reduction

100-to-1 part reduction

20-25% production costs reduction

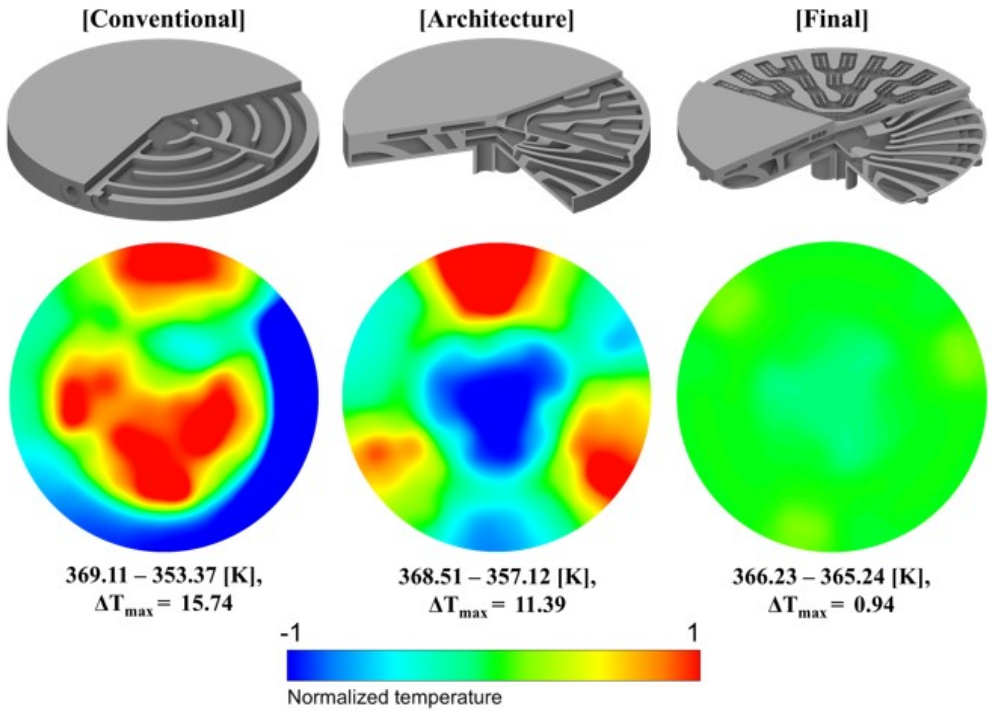


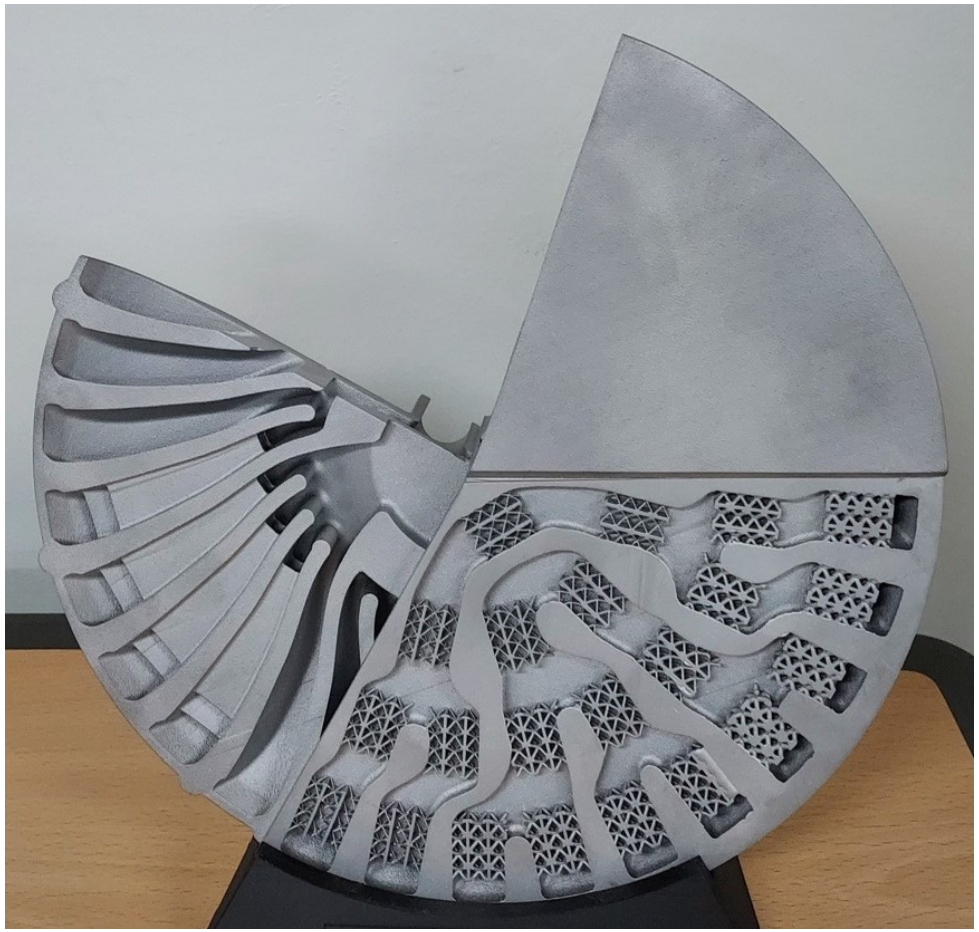
It’s easy to add features to an existing AM design, easier to assemble the finished components and, long-term, you have less testing, maintenance and service when you have fewer parts.”

ROB SMITH
COO, Optisys

DfAM redegin & optimization of a cooling chuck for wafers

Getting a uniform cooling pattern thanks to complex channels, with only 1 inlet/outlet only.





Addworks - A staged approach to build the plan and work the plan

The GE Additive AddWorks difference

- OEM and technology power user
- OEM of multiple modalities
- OEM of powder
- Producer of high-volume parts
- Qualified in highly regulated environments
- Detailed cost modeling based on production data
- Deep materials, design and manufacturing expertise in multiple modalities

A staged approach to build the plan and work the plan

Awareness & Education

Technology Awareness

- Machines
- Materials
- Part Design
- Quality
- Cost Management

Candidate Identification

- Components
- Metal AM Requirements for ASML
- Metal AM Adoption Roadmap

Development of Applications

Put theoretical knowledge to practice

Validate assumptions

Develop solutions to risks & requirements

Develop technical solutions to meet key application requirements

- Part design
- Build Job Design
- Material Properties
- Post Processing
- Inspections & Verification

Process & Industrialization

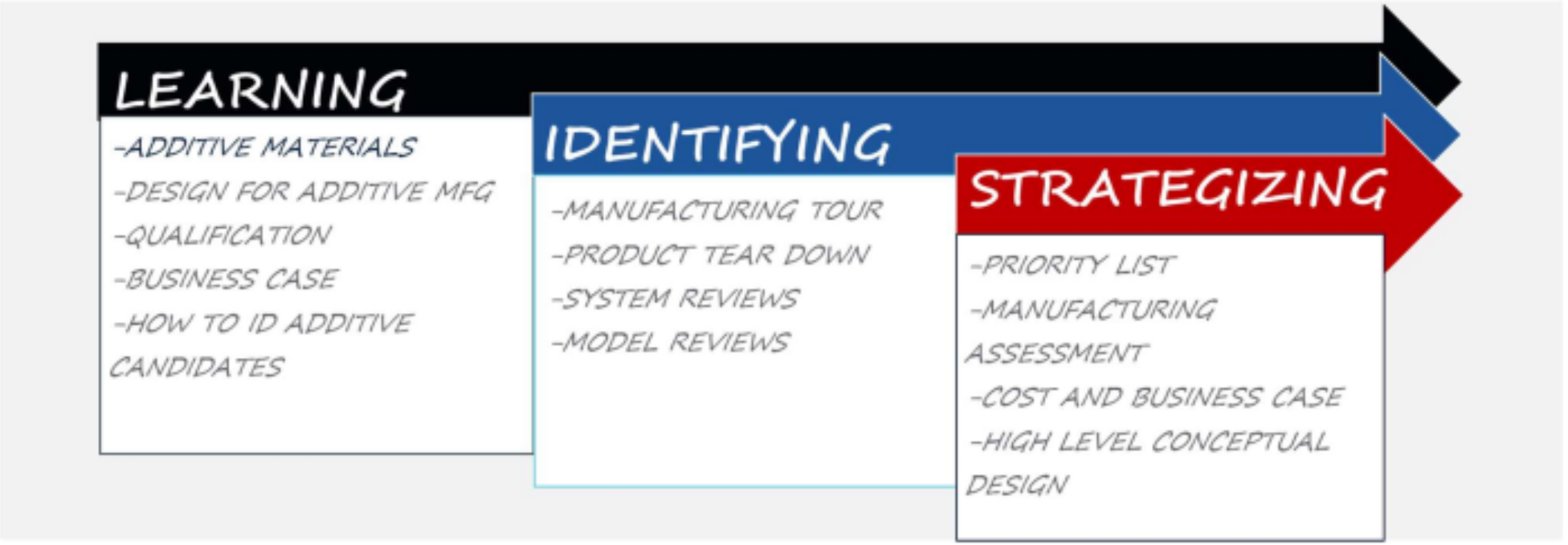
Operation of machine in manufacturing facility

Process & procedures for in-house production or purchasing of metal AM components

- Part performance
- Machine performance
- Material feedstock
- Facility operation
- Inspection procedures

Characterisation & validation of procedures vs requirements

Education & Awareness – Discovery Workshop



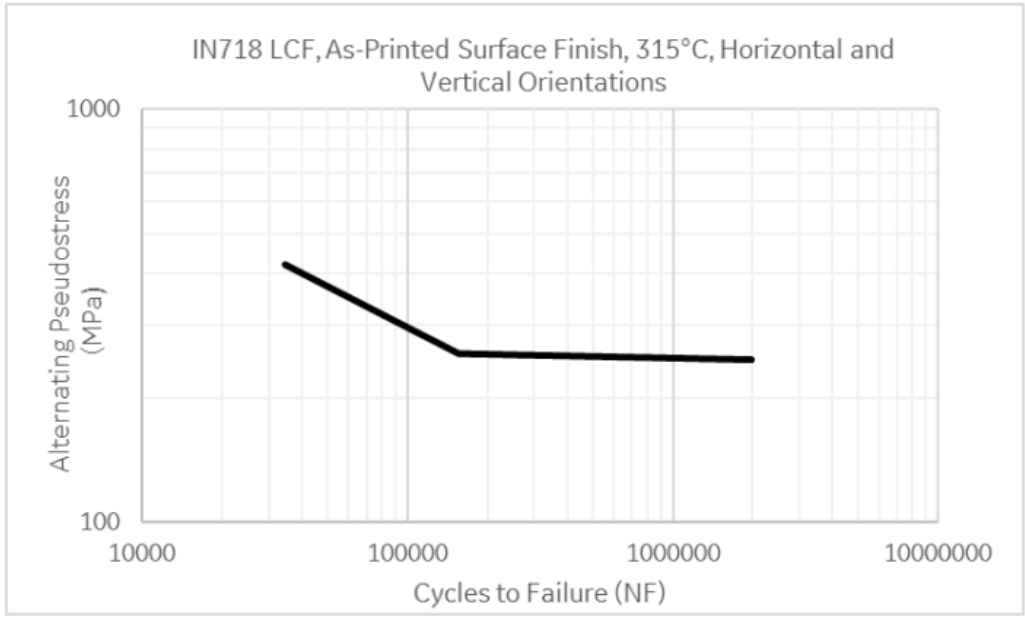
Data-driven support to engineering design

Static load – mechanical characteristics

Test Temperature: RT	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)	
Thermal State	H	V	H	V	H	V
As-Built	185	180	755	705	1065	1040
SOLN+AGE	195	195	1315	1285	1480	1450
VSR+HIP+SOLN+AGE	205	200	1100	1105	1355	1350

Ti64 printed metal properties 50µm, M2

Dynamic load – LC Fatigue



IN718 printed metal properties 50µm, M2 - LCF

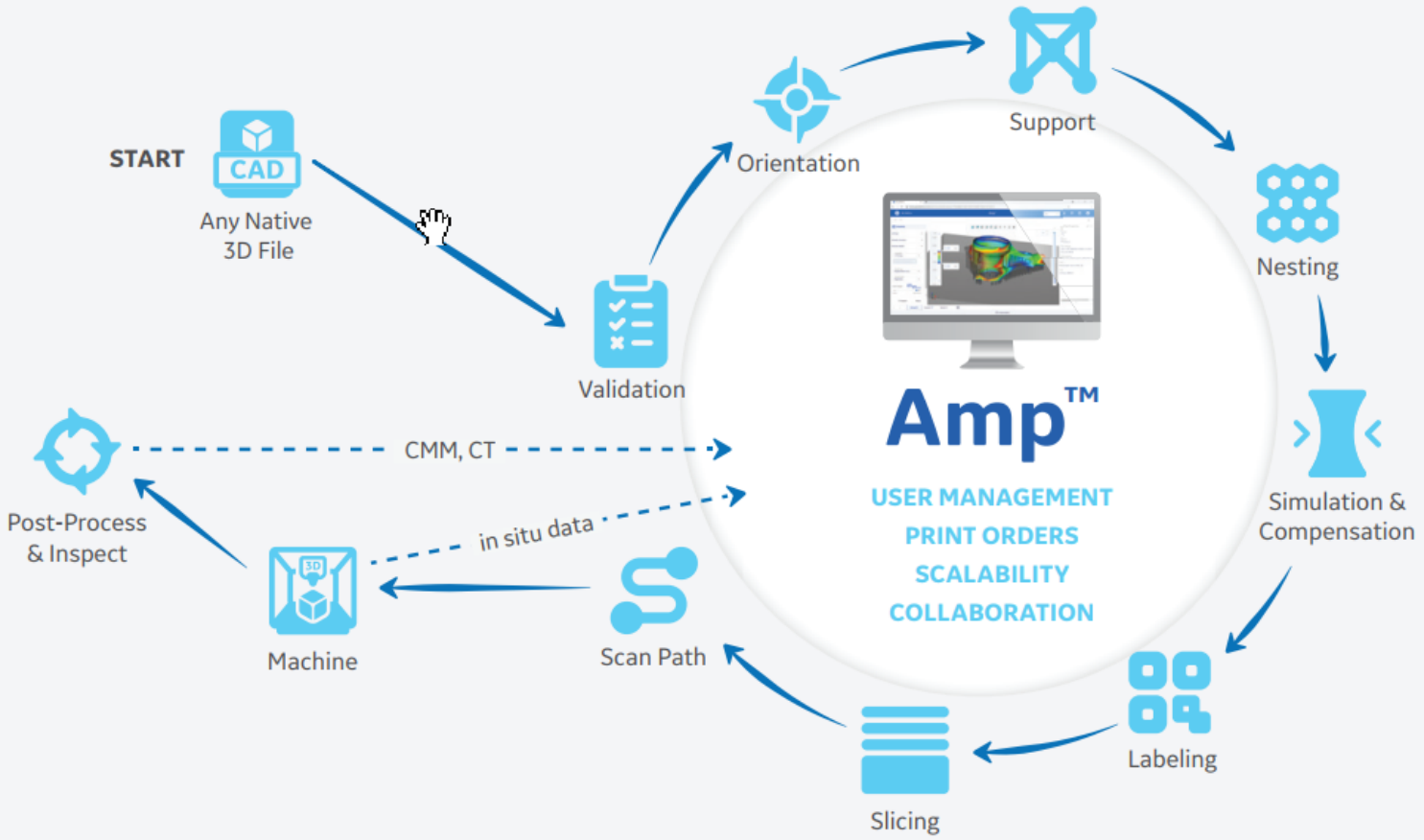
Example of GE provided data for customer engineering mechanical design

AMP software accelerates the metal AM developments

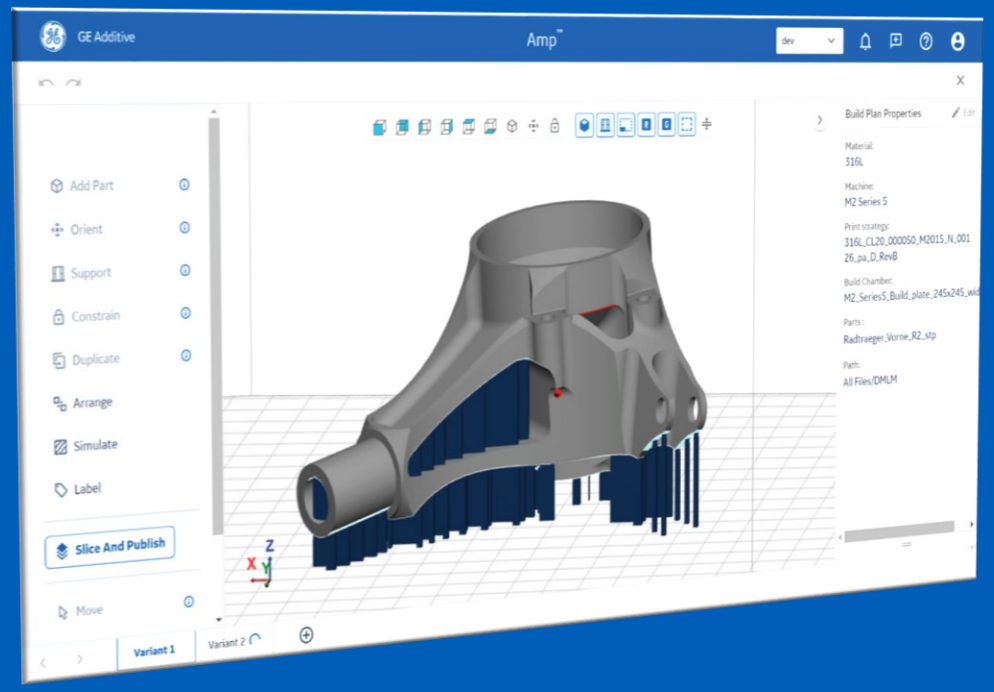
With Amp

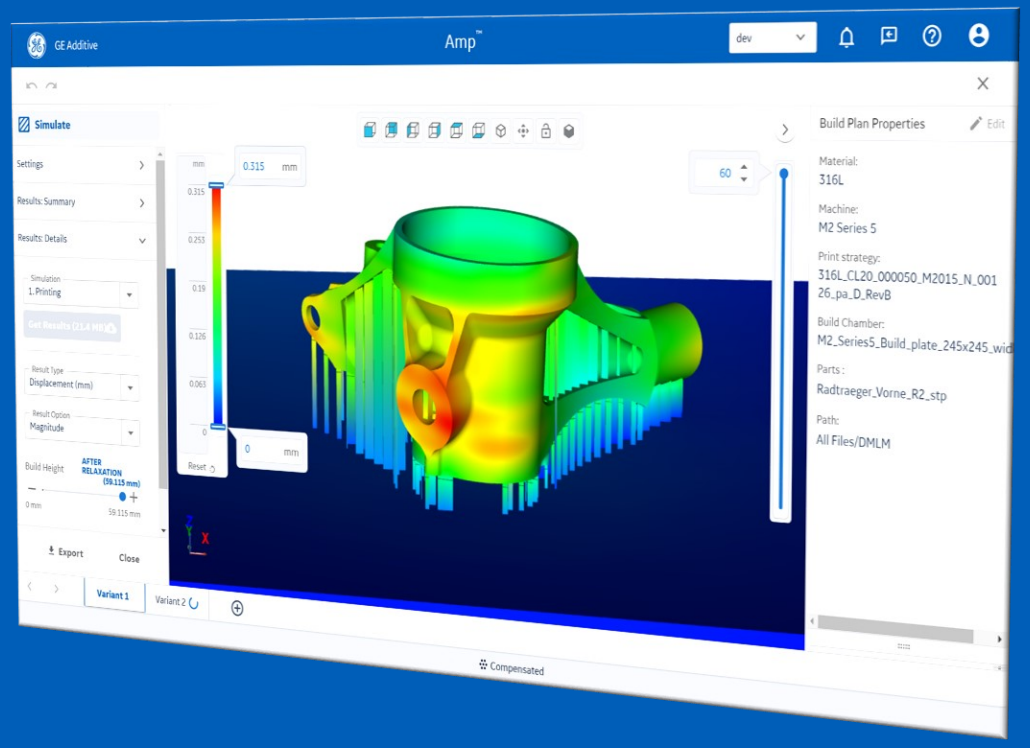
One integrated, data-centric solution

- Uses native 3D files rather than STLs
- Enables more tasks and people to work simultaneously through a flexible work process
- Provides built-in estimates of cost and time
- Significantly reduces trial and error
- Creates a complete digital thread



GE Additive's Amp™ software platform gets you to industrialization faster

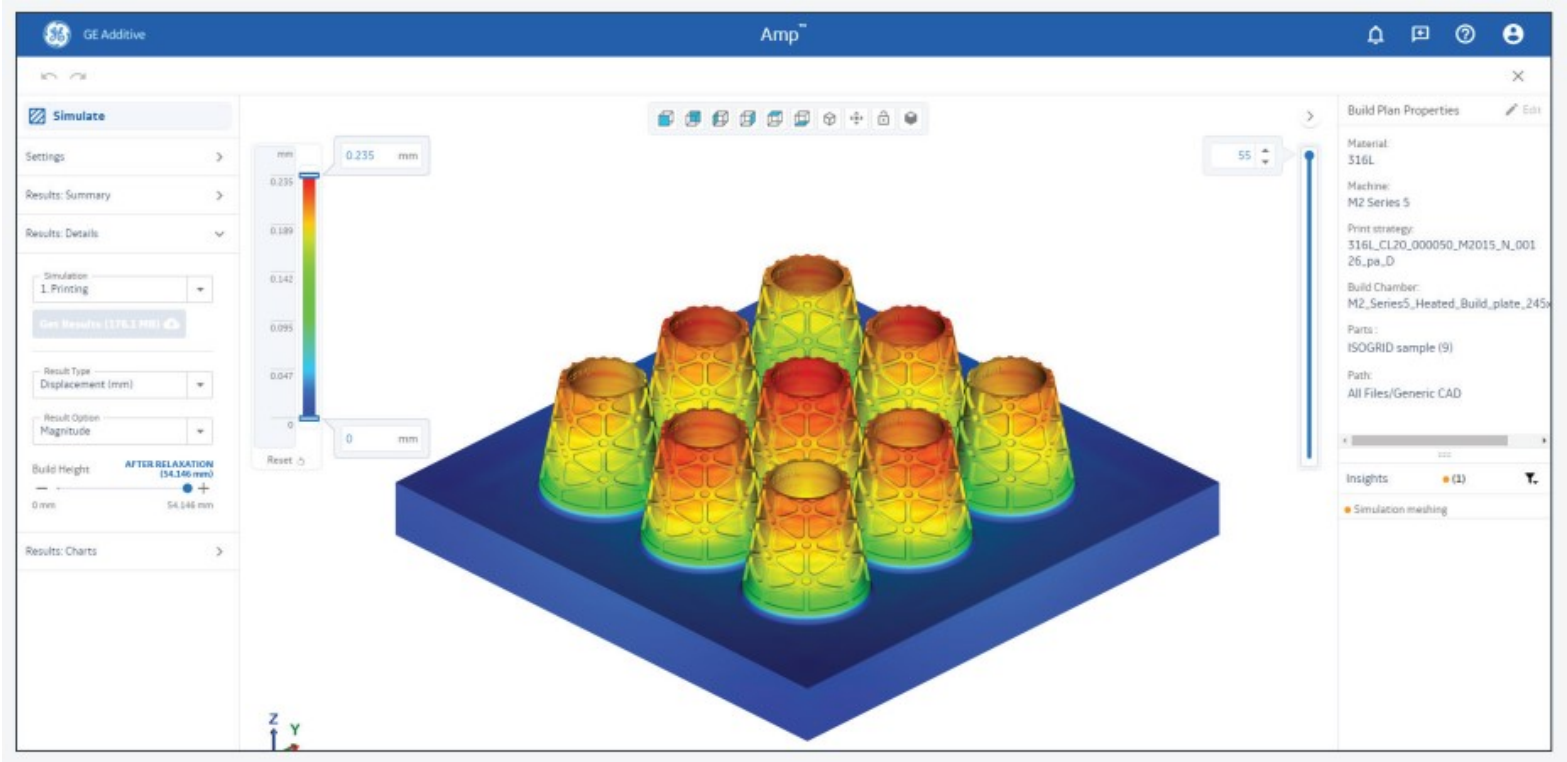




Simulation & Inspection based Compensation

Simulation – estimate the deformation of the printed parts

in order to reduce trial & error and ultimately to reduce the time and cost from design to print



Without Amp

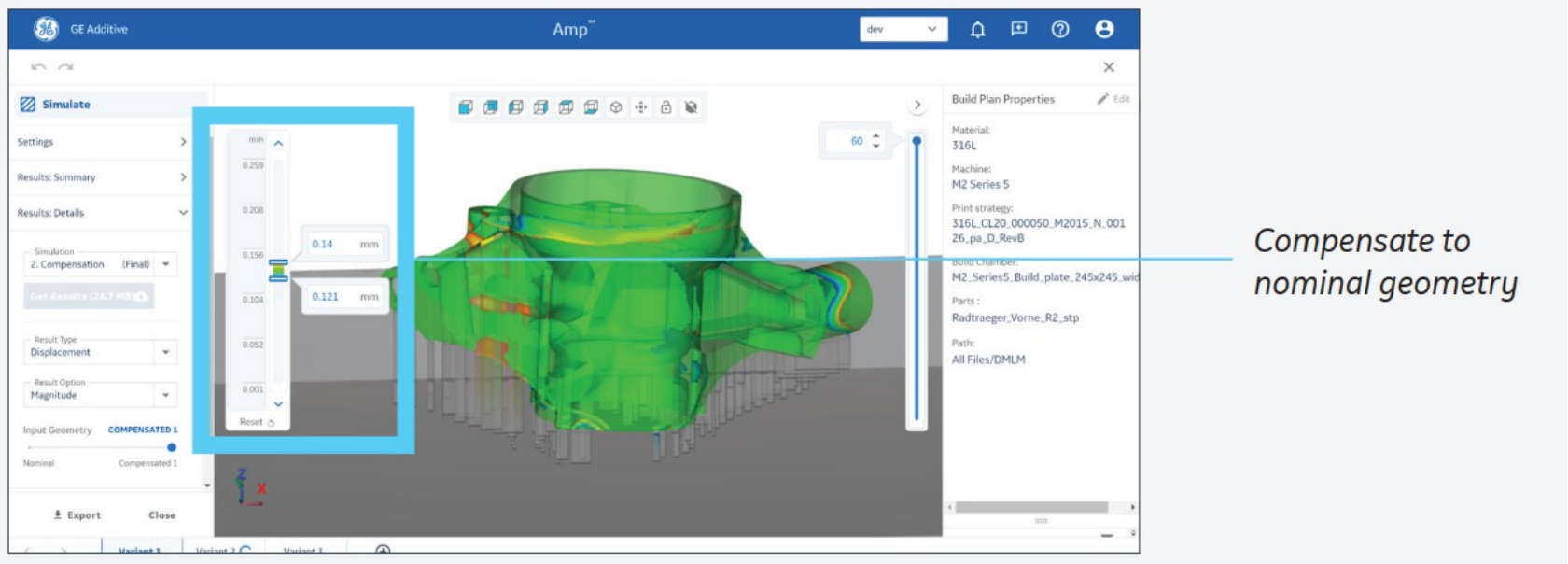
lengthy trial-and-error period testing different printing parameters to work out the right combination that delivers a suitable build plan for production.

With Amp

The software predicts thermal, mechanical stresses, enabling engineers to arrange parts and compensate for distortions.

Compensation – amend the part or build geometry

and eliminate CAD amendments to converge fast to an acceptable printed outcome



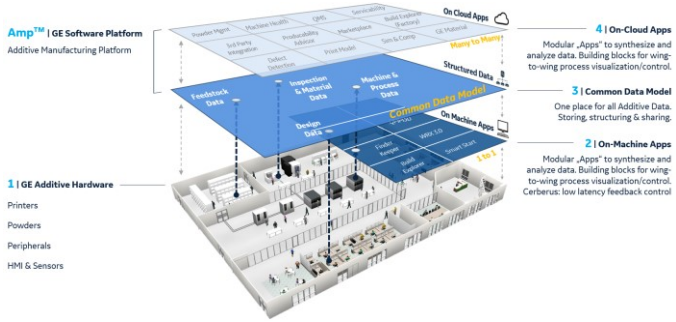
Without Amp
Manipulate the CAD geometry to compensate for distortions seen in the printing process, contributing to the tiresome trial-and-error process that leads to printing a successful part.

With Amp
Amp iteratively compensates until it finds a solution that produces a successful print

Reduce trial and error and pave a smoother, more cost-effective path to full metal additive production.

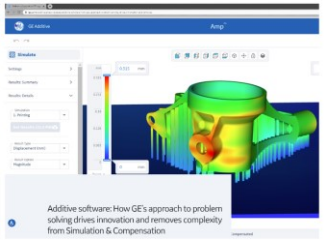
Digital Twin of the Additive Process

Reduce time & effort of physical test prints – get to first print right



Industrialize Additive

Embed GE knowledge & experience for our customers benefit



www.ge.com/additive/press-releases/additive-software-how-ges-approach-problem-solving-drives-innovation-and-removes

An easy-to-use, unsophisticated and experience-rich simulation & compensation software solution

Building a world that works